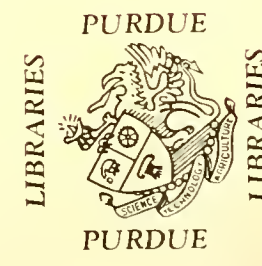
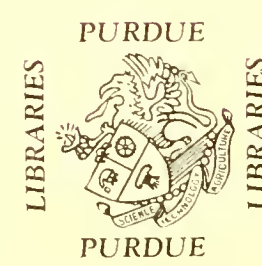
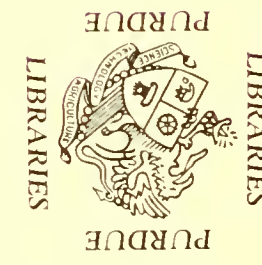
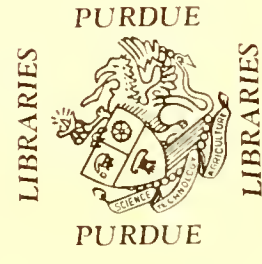
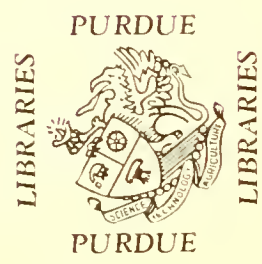
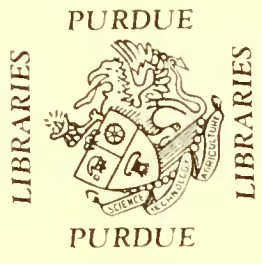
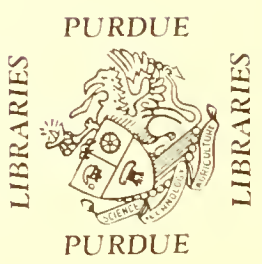
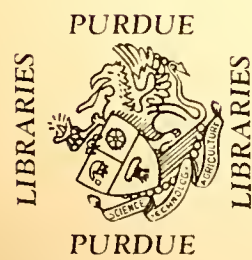
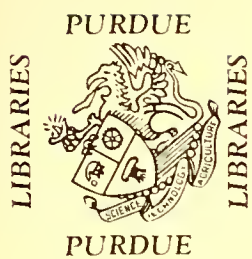
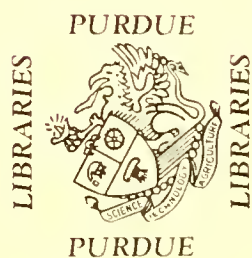
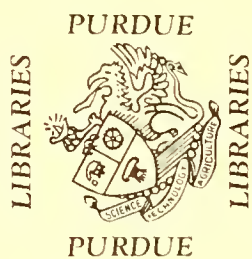


Civil Engng.

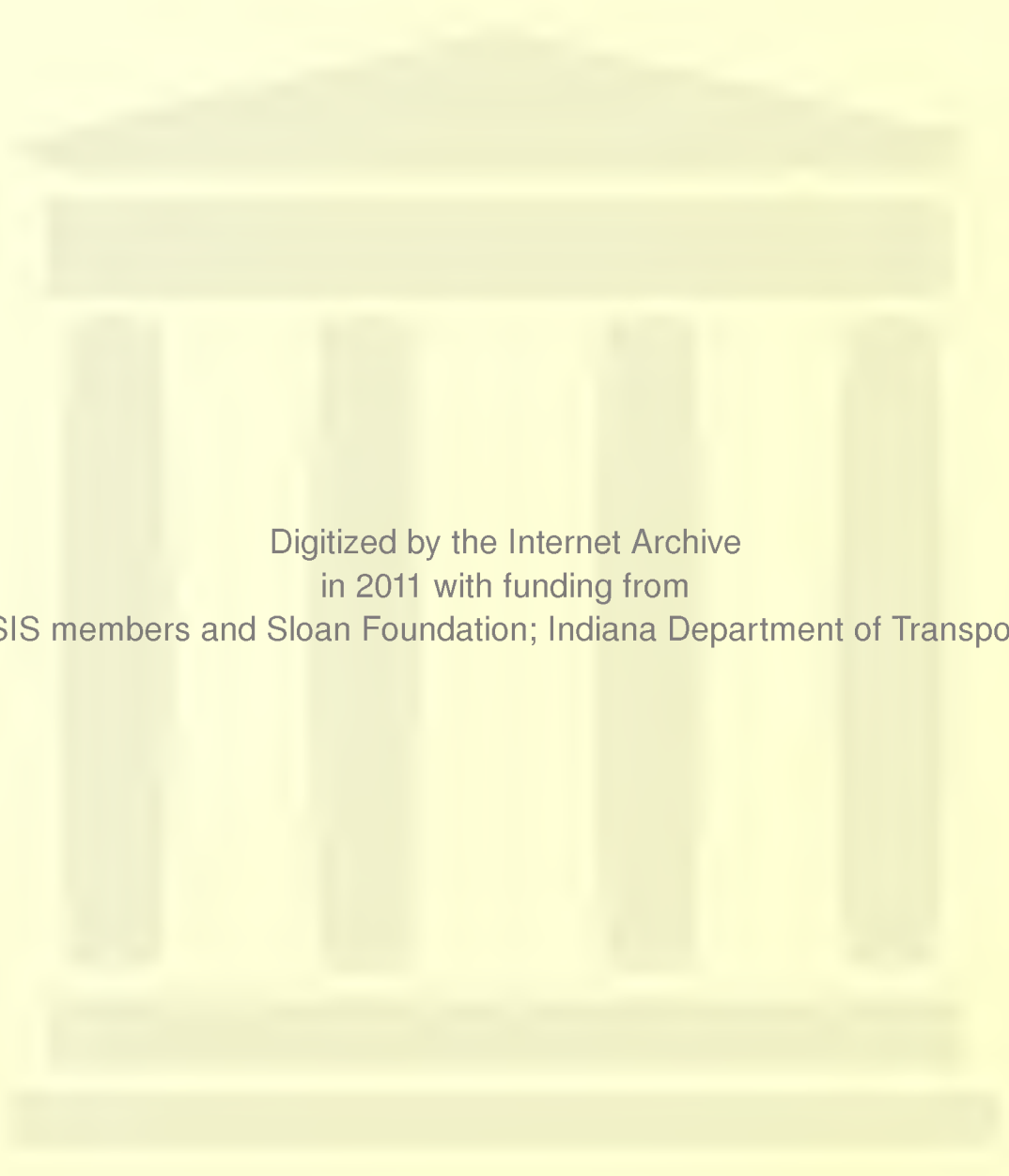




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No. 7

ROLE OF RESEARCH IN SOLVING HIGHWAY AND URBAN PROBLEMS

APRIL 1960

NO. 7

1113

Joint Highway Research Project

by

K.B. WOODS

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Final Report

AIRPHOTO INTERPRETATION OF ENGINEERING SOILS OF
KOSCIUSKO COUNTY, INDIANA

TO: E. B. Woods, Director
Joint Highway Research Project

June 8, 1960

File: 1-5-2B-32

FROM: H. L. Michael, Assistant Director
Joint Highway Research Project

Project No.: C-36-51B

The attached report entitled "Airphoto Interpretation of Engineering Soils of Kosciusko County, Indiana," completes a portion of the project concerned with Engineering Soils mapping from aerial photographs. The report was prepared by P. T. Yeh, Research Engineer and Jag. Narain, former research assistant, Joint Highway Research Project.

The soils mapping of Kosciusko County was done primarily by airphoto interpretation. However, the soil borders are justified by field investigation. To increase the value of the county soil maps, the major soil types were sampled and tests were performed in the soil laboratory. The soil testing data included grain-size analysis, plastic limit, liquid limit, optimum moisture content for maximum dry weight from standard proctor test and CBR. The soils were classified under the Unified Soil Classification System and the Bureau of Public Roads System.

An ozalid print of the engineering soils map and the test data and the appropriate classification listed in a table on separate sheets are included in the back of the report.

Respectfully submitted,

H. L. Michael

H. L. Michael, Secretary

HLM:cw

Attachment

cc: F. L. Ashbaucher
J. R. Cooper
W. L. Dolch
W. H. Goetz
F. F. Hovey
G. A. Leonards
J. F. McLaughlin

A. D. Miles
R. E. Mills
C. E. Vogelgesang
J. L. Waling
J. E. Wilson
B. J. Yoder
C. A. Hawkins (H. B. Scott)

Role of Research in Solving Highway and Urban Problems

by

K. B. Woods, Head, School of Civil Engineering, and

Director, Joint Highway Research Project

for

14th Annual Ohio Engineering Conference

April 1960

Introduction

According to Perry (1) the first Turnpike Company in Ohio to build a toll road was incorporated in Summit County in 1809 and the Ohio Highway Department was created in 1904 with a budget of \$10,000. In 56 years this great state has developed 100,000 miles of good roads with 16,000 miles in the state system. Since 1956, Ohio and other states have embarked on highway construction programs unmatched in the history of man.

What has research contributed during the first 50 years or so of highway progress? What might research contribute to this accelerated program during the next 10 to 20 years of greatly accelerated construction? Where should this research be done and by whom? Pertinent to this highway and university group is the question concerning the types of research which need attention: Are there projects directed to problems of immediate interest to Ohio only, and others directed to the solution of problems of interest to Ohio as well as to Canada, Hawaiian Islands, Mexico and the "48 states"—and perhaps the world at large.

This brief presentation will be directed to providing answers to these questions. Some of the contributions which have come from the Ohio Department of Highways and from others will be cited. Also, some attention is directed toward the contributions which have developed from the Ohio Department of Transportation. Highway progress is only one of the many problems of today.

University. Finally, the picture would be warped indeed without acknowledgment of the truly great research contributions of the Bureau of Public Roads, the highway industry itself, plus contributions from foreign sources, as for instance, the British Road Research Laboratories.

Early Research Contributions

In 1959 this author (2) raised the question as to whether or not the Civil Engineers of this country could have handled a highway program of the magnitude of the current one, 30 or 40 years ago. A quick survey of the state of the art in 1920 and 1930 will show without question that our capabilities then were extremely inadequate to cope with modern highway problems. Since that time, however, the collective research contributions of Highway Departments, universities, the Federal Government, materials producers, added to the great efforts of committees of the Highway Research Board, American Association of State Highway Officials, and the American Society of Testing Materials, have made possible the ability of Highway Departments to execute their present responsibilities and the industry in general to meet the demands of this tremendous building program. It is to the credit of the Bureau of Public Roads and the Congress of the United States that funds to pursue basic programs of research have been provided currently to produce findings which can be used to guide the financing, planning, design, construction, and operation of these modern highways.

In considering the low state of the science of road building forty years ago it is surprising to note an occasional section which was built then, still in service--with a considerable mileage still being used as bases for modern pavements. Some concepts of basic design were developed and are being developed through controlled test sections and test roads designed specifically for this purpose. Examples of such projects are the field experiments conducted by the Bureau of Public Roads at Arlington, Virginia (3), and Connecticut Avenue, Washington, D. C. (4). At the same time the results from the "Bates Test Road" (5)

established a pattern of design which lasted until about 1945. During and after the second World War, pavements constructed under these design concepts failed badly, especially in sections of the country where clay-like soils predominated and under conditions of a high volume of heavy loads (69). The need for a new design approach was thus indicated (120, 124). Test roads again became popular. The Highway Research Board undertook work on a road project located in Southern Maryland (6). The Eastern Association of State Highway Officials sponsored the so-called "EASHO Road Test" (7, 8) and the 23-million dollar AASHO Road Test (9) was conceived, built and, at this writing is still under test.

During this 40-year period of "test roads," a wide variety of highway research was performed in the laboratories of the Bureau of Public Roads, universities, State Highway Departments, materials producers, and others. The highway periodical "Public Roads" came into the picture at this time and the internationally known "Highway Research Board" was organized in 1920 under the auspices of the National Research Council (established by the National Academy of Science in 1916). The American Association of State Highway Officials was organized in 1934. Organized programs of research began to appear (10, 11, 12). The early technical literature indicates great interest in low-cost roads such as "sand-clay" (13, 14, 15, 16), and "bituminous-earth" roads (17). Bituminous pavements were constructed on city streets long before the turn of the century and by 1910 considerable literature was available (18, 19). Brick (20, 21) was used commonly as a wearing surface and the structural design of pavements was, and continues to be, simplified in great detail (22, 23, 24). Such names as Hesse (25), Ladd (26), Hentzner (27), Burton and Bankleman (28), Boyd (29), and Terzaghi (30, 31, 32) began to appear in the literature during this period because of increased interest in highway subgrades. The classical work on the gradation of aggregates and the development of the well-known "Fuller's Curve" was published in 1907 (33) and with the efforts placed on highway construction, research programs were expanded in the fields of materials research. Committee D-4 on Road and Paving Materials of

the Highway Board organized in 1900, primarily to develop methods of tests and specifications for pavements including wood block, granite block, brick, and bituminous mixtures. Committee C-9 on Concrete and Concrete Aggregates was formed in 1924 under the leadership of Sanford E. Thompson (33) but Committee D-18 on Soils for Engineering Purposes was not organized until 1936.

Soon after 1920 interest was evidenced in some of the broad aspects of highway engineering including finance (34), economics (35, 36, 37), traffic and safety (38, 39, 40, 41, 42, 43, 44), and the relationship of highways to other forms of transportation (45, 46, 47). The current great interest in continuing research on these and many other facets of highway engineering is indicated by the fact that over twenty-six hundred people were registered at the January, 1960 annual meeting of the Highway Research Board in Washington, D. C.

Early Cooperative Highway Research in Ohio

One of the most outstanding cooperative efforts between the Ohio State University and the Ohio Department of Highways was the highway research conducted in 1920, by Professor F. H. Loo (48, 49, 50, 51, 52). Interest on the part of Professor Loo in the subject of highway soils was created by a remark made by a member of the advisory commission to the Ohio Department of Highways to the effect that "...highway engineers were showing extreme lack of judgment in the location and construction of roads upon the least stable of soils" and that "...engineers were cutting off the good soil and wasting it in order to lay down the road upon plastic, compressible clay soil" (48, p. 1). This research project was organized as a joint undertaking between the University, the Highway Department, and the Bureau of Public Roads. Included in the program were extensive laboratory studies and wide-scale field work including the installation of 15 widely scattered subgrade-treatment sections in which a variety of materials were employed. Included were several types of granular bases and many types of chemical treatments including cement, lime, bituminous materials, and others. It was this author's privilege, in the late 1930's to inspect thoroughly all of these field experiments still in service. One result of this survey was the development of a personal opinion that Professor Loo would have "discovered" soil cement in the 1920's had he recognized the need for control of mixing water and of densification of the soil-cement mixture.

A second important development resulting from the University-Highway Department cooperation was that reported by Taylor et al in 1935 (53), in which some outstanding information was developed for the Bridge Bureau conveying the predetermination of pile requirements for bridge foundations.

A little later, in 1936, the author was privileged to report through the Ohio State Engineer, a different station on five years of development toward

the Bureau of Tests in the general field of highway soil mechanics (54). Included in this report was one of the early sets of typical embankment control curves averaged from 461 Ohio soil samples tested in 1936. This work has been continued and in 1958, Joslin (55) presented curves averaged from 10,000 samples. The curves are widely used on various types of earthwork throughout the country.

Other examples of cooperative work between the University and the Highway Department can be cited--however, these represent outstanding cases and indicate a long-time spark of interest on the part of both organizations toward cooperative highway research. Then too, Ohio has long been well-represented by E. K. Litchell and other members of the staff of the Bureau of Tests and by many engineers from the central office, and by members of the University staff on committees and at meetings of such well-known organizations as the Highway Research Board of the National Research Council, the American Society of Civil Engineers, The American Society for Testing Materials, and American Association of State Highway Officials, American Concrete Institute, Association of Asphalt Paving Technologists, and others.

Significant to the above mentioned cooperative programs is the fact that all three involved highway soil mechanics. Consider for a moment the potential if the entire spectrum of highway engineering is opened for joint research effort. Highway engineering, in the broad sense, stretches beyond the scope of Civil Engineering itself, touching as it does on finance, administration, taxation, economics, engineering law, and even the broad field of urbanization itself. These disciplines are in addition to the conventional Civil Engineering sciences such as Structural Engineering, Soil Mechanics and Foundations, Materials, Construction, Traffic Engineering, and Operations. The great schools and universities of this country and Canada are equipped, and are interested in better services to the separate highway departments.

Cooperative Highway Research Programs

With the great scope of unsolved problems encountered in the highway field it is only natural that the practicing highway engineer of the Federal, State, and local governments and the professional staffs of the institutions of higher learning would become interested in joint research efforts. Many such programs have been developed in the separate states of the United States and in some of the provinces of Canada. As a general rule, the cooperative efforts between Highway Departments and universities--and frequently with Public Roads as an important third party--have two main objectives, namely (a) the solution of problems confronting the highway agency by the application of research techniques. These may be immediate or long range problems; both basic and applied research have found a place, (b) the encouragement of promising young engineers to pursue graduate programs in Civil Engineering so that they may be able to contribute through their own research and through teaching in universities or in the employ of Federal, State, local government agencies, or the highway industry in general. It is important to note here that the highway industry itself has some considerable responsibility in contributing to research and development and to the fellowship programs of our colleges and universities dedicated to graduate programs.

Many of the cooperative programs have been very successful. Iowa State University and the University of Illinois have had long-term informal arrangements with the Iowa and Illinois Highway Departments respectively--frequently with Bureau of Public Roads participation--to produce important contributions. In more recent years, more formal arrangements have been initiated in both states.

Both formal and informal arrangements between the Highway Department and a college or university are common in the United States and Canada--and interest in developing cooperative highway research programs, with Public Roads as one of the sponsors is increasing rapidly. Among the states with informal arrangements can be listed Florida, Kansas, Ohio, Minnesota, and Texas. Various types of

formal university-highway department cooperative programs have been established in such states as California, Georgia, Indiana, Kentucky, Maryland, Massachusetts, Michigan, North Carolina, Tennessee, Virginia, Washington, and the Provinces of Alberta and Ontario, Canada.

Important research contributions by highway departments themselves include California, Iowa, Minnesota, Missouri, New York, and Ohio--to name a few.

Indiana's HIRP

One of the early cooperative highway research undertakings was the Joint Highway Research Project started informally at Purdue University in 1936 (56). The organization was established as a result of an agreement between the Chairman of the State Highway Commission of Indiana and the Dean of the School of Engineering at Purdue University. During the first year the Commission budgeted \$25,000 for research and on March 11, 1937, the organization was established by an act of the State Legislature which permitted the Commission to allocate up to \$50,000 annually for the operation of the research organization. In 1949, the legislature revised the 1937 act, to raise the permissive amount the Highway Department may allocate to the University. The offices and laboratories are located in the Civil Engineering Building at Purdue University.

Close contact is maintained with the Highway Department through an Advisory Board. The Board outlines policy, receives and recommends projects, receives reports on projects, approves release of research data, and recommends to the Highway Department and the University the quarterly funds to be allocated. Through contact with the program of research, the Highway Department members are able to guide the research endeavors toward the most pressing Indiana highway problems and to apply quickly the knowledge gained. In turn, the University board members and staff are better able to pool the University resources toward the development of research projects designed to solve some of the highway problems of the State.

The Highway Research Project is a unit in the Engineering Experiment Station and is administered by the Head of the School of Civil Engineering, who also serves as Director. At the present time there are nine research divisions, as follows: Soils, Concrete and Rigid Pavements, Bituminous Materials and Flexible Pavements, Aeronautics Interpretation, Chemical, Traffic, Economics and Administration, Structures, and Hydraulics. These divisions are the scene of independent work on the

area of research programs, and most of them are the source of educational content at the graduate and undergraduate level. At the present time, the staff of the project includes 24 full-time employees and 15 half-time graduate research assistants. From 50 to 75 undergraduates are employed on a part-time basis to assist on research projects. In addition to the many dozens of research papers produced by the staff in the 24-year period of the Project's existence, general progress reports have been released from time to time (57, 58, 59).

In presenting a few highlights covering the work of the Joint Highway Research Project, the research projects are divided into two types--namely: those of State and local interests, and those of State and National interest.

Soil Mechanics and Airphoto Work. An ideal area of cooperative research is in the field of distribution and engineering characteristics of soils. This is especially true in the Midwest where strong research and graduate programs have developed as at Purdue University and here at Ohio State, for instance. The State Highway Commission of Indiana feels strongly that one of the major contributions to their programs has been the research on Indiana Soils (60) published in 1942. A generalized engineering soils map of Indiana is included in this bulletin and the soil survey information was studied and presented in engineering terms. Research has continued for the past 17 years in refining engineering soil boundaries in various counties of Indiana (61). There is good reason to feel that this work will continue at an accelerated rate as a result of the development of a new Indiana project which will include participation by the Joint Highway Research Project with the Purdue Agricultural Experiment Station, the Soil Conservation Service, and the Bureau of Public Roads. This kind of cooperative research is almost ideal for the state of Ohio. Civil engineering graduate programs can be greatly enhanced while the highway department (counties and cities) can be provided with excellent information on the distribution and engineering properties of the soils of the State including considerable information on materials of construction.

At Purdue, interest has continued for 20 years or so in connection with the fundamental properties of soils, such as frost action (62, 63), soil stabilization (64, 65, 66, 67), base courses for rigid and flexible pavements (68), the bedding of pavements (69, 70), and soil explorations for highway projects (71, 72, 73, 74, 75). Included among some unusual soil studies is the work of Coleman et al. (76), on deflection measurements made from deep-seated bench marks (76).

and the very interest in soil of erosion factor (77) on the use of contour protection for highway subgrade soils.

The Joint Highway Research Project also operates a large airphoto interpretation and photogrammetric research laboratory. This unit is used to develop the art of airphoto interpretation and the science of photogrammetry as applied to the location and planning of urban areas and highway systems. The laboratory is primarily concerned with the development of the use of aerial surveys to evaluate watershed characteristics, engineering soil types, location of aggregate and borrow materials, and special applications of photogrammetry.

The State of Indiana has available only about 40% of the required number of 1/24,000 topographic map series. For this reason, a drainage mapping program of individual counties was instigated in the mid-1940's (73). The aerial photographs were used to delineate ephemeral and perennial drainage channels. The 92 counties have been completely mapped and a County Drainage Atlas with maps at a scale of 1 inch equals 2 miles has been prepared. The atlas provides complete data on the drainage density and drainage areas for planning purposes (79).

The photogrammetric section develops special studies that cannot be scheduled in the Highway Department's Photogrammetric Laboratory (80). Graduate students have worked on such studies as the "Photogrammetric Measurement of Ideal Day Plantations in Highway Construction." Another project is the investigation of the development at selected interchanges on the Interstate Highway in Indiana to determine warrants for right-of-way control (81). Some interesting work has also been completed in the use of aerial strip photography for various highway and airport applications, including the making of performance surveys (82).

Concrete and Concrete Aggregates. A second very practical area for cooperative research is in the field of materials of construction. Each of the geographical, geological, and major political units of the continent may have problems with materials, peculiar to the particular unit, and not necessarily in common with adjacent areas. Ohio may have problems in common with all surrounding states, i.e., Pennsylvania, West Virginia, Kentucky, Indiana, and Michigan. However, it is likewise true that all of the problems with native materials in Ohio are not in common with any of these sister states. It is practical then to consider a state-wide, cooperative research program on the distribution and engineering characteristics of the materials commonly used in highway construction.

Using again the highway research in Indiana as an example, large laboratory and field programs have been underway for about 20 years--and the laboratory programs are being continued. One of the early contributions was made possible through detailed studies of the performance of concrete pavements. The research produced a clear correlation between the source of coarse aggregate used in construction and the satisfactory or unsatisfactory performance of the pavement (33*).

* This paper was chosen as the 1945 Highway Research Award.

Furthermore, it was observed that the susceptibility to blow-ups was an indication of the use of poor-quality, non-durable aggregates, which when used in pavements, resulted in short life--especially in areas of severe frost with subgrades of clay-like characteristics. This research was of great importance in developing specifications (34, 35) for portland cement concrete aggregates but it also had a significant influence on the design of rigid pavements in connection with the abandonment of the use of expansion joints. This work led to many detailed laboratory studies of aggregate and of concrete. Chemical investigations were reported by Smith (36, 37). Indiana limestone aggregates have been

studied in an effort to understand their performance in frost action. The study involved the porosity, permeability, and absorption properties of the materials and good correlations were obtained between these properties and the durability histories. Some of this work was reported by Lewis, Dolch, and Woods (88) and more recently by Dolch (89). The gravel aggregates of Indiana have also received much research attention with special emphasis on chert and other deleterious substances (90) together with corrective measures which might be employed (91). Such areas as structural concrete in the state (92) and fatigue of air-entrained concrete (93) have also received attention.

Pavement slipperiness and paving-mixture design from this viewpoint are becoming very important as the volume and speed of traffic continues to increase. Materials from which pavements are made need to be re-evaluated from the standpoint of their resistance to the polishing action of traffic (94). The ramifications of this problem are many and, in any particular state, research is needed to guide the highway engineer in the use of materials and design of mixtures to provide practical answers to the problem. The Joint Highway Research Project has undertaken laboratory studies to classify materials as to polish resistance (95). The mixture design problem has been investigated to provide the information necessary to make best use of the materials available. The most recent work on this problem concerns the use of available sand for producing mixtures for as-slicking purposes. The laboratory sand-mix study has evaluated such factors as particle shape, silica content, and sand grading (96). The cooperative study has now been carried to the field for the purpose of developing field data to correlate with laboratory results and thereby to establish specifications and design criteria (97).

Bituminous Materials Research. Bituminous materials and bituminous-aggregate mixtures are receiving increasingly greater attention in highway-research laboratories as a result of (a) continuous increases in the traffic volume and loads, (b) increasing use of bituminous mixtures for flexible pavement construction and for resurfacing. Again, some of the research of the Joint Highway Research Project can be used to illustrate how a University-Highway Department cooperative program can function to provide research data for use in solving current highway problems. The basic, long-time program which has been underway almost since the inception of the cooperative work at Purdue, is concerned with the fundamental characteristics of bituminous-aggregate mixtures as related to their ability to carry traffic loads. In Indiana, this involves a very wide range of mixtures which are used under a variety of conditions of service, ranging from low-cost secondary surfaces to high-grade bituminous concrete. This kind of long-range program requires frequent observations of field performance and great effort on the part of the research team to develop correlations between performance and laboratory methods of test. Durability of mixtures is of course another important subject for research.

One of the outstanding contributions in this area of research has been the long-term study covering the evaluation of several laboratory tests pertaining to the design of the mixtures and performance of these mixtures under traffic. An early study of this kind covered evaluation of the Marshall's ability test as a method of indicating strength values (98). A more recent study was concerned with an evaluation of the Hveem Stabilometer method as a strength test, particularly as applied to mixtures of the open type and as opposed to the dense mixtures to which the test is normally applied (99). In evaluating Marshall and Hveem methods, use was made of rational tests such as unconfined and triaxial compression (98, 100). One of the most important aspects of mixture design for any concrete-

tion agency is the evaluation of mixture variables as affected by the materials available for use. Many of the studies cited above bear on this problem (96, 99, 100). The evaluation of such factors as aggregate shape, both in the coarse and fine aggregate, is a case in point (101, 102). At Purdue there has been a continuing effort to understand better the effect of load variables, as determined by service conditions, on deformation characteristics of bituminous mixtures. Temperature, confining condition, rate of loading and repetition of load are the major factors studied (103, 104). The application of the concepts derived from such studies in order to give practical values to laboratory programs requires close cooperation between the laboratory and the field and a close university-Highway Department relationship. Mix design procedures have been modified to fit the conditions in Indiana (105) and performance data are obtained through test sections installed by the Highway Department and evaluated by Purdue personnel (106).

Another area to which the research organization has been able to make significant contributions concerns the durability characteristics of bituminous mixtures. The nature of this problem is such as to make evaluation difficult, but fundamental relationships have been brought out by laboratory studies (107). The application of the sonic test to the stripping resistance of bituminous mixtures, because it is a non-destructive type of test, has enabled long strides to be made along the way to solving this problem (108).

Traffic Engineering and Highway Planning. In recent years Joint Highway Research Project efforts in the areas of traffic engineering and highway planning have been expanded and the outlook is for continued expansion, especially in urban planning and transportation economics. These contributions to the Indiana transportation system and specifically the State Highway Department of Indiana have been of major importance. Some of the studies which have proved particularly valuable are studies of highway impact, highway "needs," traffic accidents, the characteristics of traffic on Indiana highways, origin-destination surveys, the location of slippery road sections, roughness of highways, administration and organization of state and local highway departments, and county highway planning.

The initial studies of the impact of highway bypasses are well known and specifically in Indiana resulted in a broader and wiser application of the principle of controlled access (109, 110, 111). Impact studies are continuing and currently an attempt is being made to evaluate the influence on an urban area of a major highway improvement and the impact in rural and urban areas of a section of the Interstate System. The Project staff with the assistance of personnel from the State Highway Department conducted a "needs" study of the highway system in Indiana, which contributed heavily to the passage by the State Legislature, and the almost universal acceptance, of legislation which in turn provided much-needed highway revenue (112, 113). Much information obtained in this study is currently being used in highway planning in Indiana and a sufficiency-rating study which was a part of the needs study provided the impetus for the adoption by the State Highway Department of this priority tool.

In the area of traffic safety, recent research projects have developed relationships between elements of the roadway and accidents, and methods of analysis have been developed which provide for the determination of the causes of accidents in terms of accident location (114). The determination of the causes

of this latter research resulted in the finding and the subsequent minimization of a major cause of accidents at 27 out of 33 high-accident locations. Research just completed in this area has also produced a technique of accident analysis which results in the efficient location of slippery sections of highway so that they can be "deslicked." The method not only locates slippery sections but also assigns a priority of remedial action which considers the slipperiness of the pavement and the volume of traffic on the highway. The technique provides a selection of sites which correlated very well with the results of skid tests made by the vehicle stopping distance method, a technique which also was perfected by research in the Joint Highway Research Project. Staff members have actively cooperated with the Metropolitan Survey Unit of the State Highway Department and have assisted in the performance of five urban origin and destination studies while at the same time using the data for research on methodology, analysis, and use of these surveys. Speed trend studies have now been conducted for the past 20 years and these studies along with a study of the volume characteristics of traffic have been of value to the Highway Planning Survey Unit of the State Highway Department. The Project also developed a roughometer for the Highway Department and has delivered it to them for their regular and continual use.

Local roads have also received attention in Project research and the development of practical methods of local road identification, classification, and priority of improvement have been developed (115, 116). In order to provide assistance to local authorities of cities and counties a Traffic Engineering Service Unit has been established to advise and study local problems (117). This Unit receives many requests for assistance from local authorities and the good public relations and subsequent improvements in highway travel in these communities are obtained with a small expenditure of time and money.

Other Important Studies. The Project also cooperates with the Highway Planning Survey of the State Highway Department by conducting some research studies

which are partially financed with Highway Planning Survey funds. At the present time several such studies are in progress including research on the Hydraulics of Arch Bridges (118). The breadth of Indiana's highway research program is further reflected by the work done in economics (119), finance (120), structures (121), and design (122, 123, 124).

Urban Research

Highway transportation is deeply involved with all other methods of transportation and especially with the entire problem of urban development. Work in this area needs immediate attention and your author strongly recommends careful consideration toward the development of strong programs in both areas. Many highway departments are already interested and there is much interest on the part of the Bureau of Public Roads.

Woodbury in his excellent report presented at the January, 1960, meeting of the Highway Research Board (125) in his concept of a new pattern of urban settlement, states that "More than two-thirds of the national population increase is going into standard metropolitan areas outside of their central cities." He also concludes that "...shockingly little is being done to understand this major phenomenon of the times, or to prepare for coping with its problems, or for making the best of the opportunities it presents." Davis commented at the same meeting (126) that, "It seems obvious that research into the problems of the functioning of the urban complex requires bringing into play the competences of a number of disciplines...." In the transportation and related fields important areas need immediate attention. To name a few topics, consider some of the following:

1. The development of better standards and techniques for origin and destination surveys.
2. Commuting and mass transit, including costs, finance, and use.
3. Inter-community travel.
4. Parking and storage terminals.
5. Expressways, bypasses, subways, and use of helicopters.
6. Inter-fringe travel, trip length, and limited access.
7. Problems in the field of political science, including city and town governments, zoning, inter-government relations, authorities and commissions, and inter-agency relationships.

8. Legal and engineering problems such as land acquisition and control, use of eminent domain, building codes, government ownership, and control of traffic.

9. Economics -- i.e., use of natural resources, residential-business-industrial patterns, land use, ownership of utilities, etc.

10. Public and private housing, and slum clearance.

11. Use of water for power, cooling, etc., flood control, sanitary engineering, and services and utilities, public health and hospitals.

12. Urban development in general.

13. Problems of finance such as taxes, rentals, housing, private, state, and Federal grants, bond issues, etc.

14. Problems of fumes and noise.

In looking at this problem it should be noted that much research has been performed and that a great deal more is underway. Publications of research findings are widespread including suggested programs of research (127, 128, 129, 130).

Conclusions

One of the best summaries this writer has seen on the value of highway research has been made by Davis (126) in his chairman's address at the January meeting of the Highway Research Board. He summarized the report prepared by Mr. E. L. Holmes of the Bureau of Public Roads as follows: "...the Committee estimated that research activity related to highway affairs in the United States in 1958 involved an expenditure of some \$17.6 million, which was 0.18 percent of the direct expenditures for highways (including design, construction, maintenance and administration) in that year of almost 10 billion dollars. The investment in research would thus appear to be only of the order of 2 mills per dollar of direct expenditure on roads -- a rather small proportion of that is considered by many industries to be an adequate investment in the solution of future problems."

It has been a pleasure to have had this opportunity to have been with you. I hope my brief remarks will encourage some of you to pursue programs of highway research.

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